

**Improving Forensic Casework
Analysis and Interpretation
of
Gunshot Residue (GSR)
Evidence**

by

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CERTIFICATE OF AUTHORSHIP / ORIGINALITY

I certify that this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Dedicated to the memory of

Robin Keeley

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and his contributions to scanning electron microscopy
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List of Abbreviations

AAS – atomic absorption spectrometry
ABS – Australian Bureau of Statistics
ADI – Australian Defence Industries
2-A-4,6-DNT – 2-amino-4,6-dinitrotoluene
4-A-2,6-DNT – 4-amino-2,6-dinitrotoluene
2-ADPA – 2-amino-diphenylamine
4-ADPA – 4-amino-diphenylamine
AFP – Australian Federal Police
Al – aluminium
APCI – atmospheric pressure chemical ionisation
API – Atmospheric Pressure Ionisation
ASV – anodic stripping voltammetry
Ba – barium
BC – butyl centralite
BN – Bayesian network
BSE – back scattered electron
Ca – calcium
CAD – collision activated dissociation
CCI – Cascade Cartridge Industries
CE – capillary electrophoresis
CF – Clean-fire
CSI – crime scene investigator
CSSB – Crime Scene Services Branch
Cu – copper
DAL – Division of Analytical Laboratories
DBP – dibutylphthalate
DDNP, diazo – 2-diazo-4,6-dinitrophenol
DEP – diethylphthalate
DFA – Delta Frangible Ammunition
DMP – dimethylphthalate
DNA – deoxyribonucleic acid
DNB – 1,3-dinitrobenzene
2,4-DNDPA – 2,4-dinitrodiphenylamine
DNT – dinitrotoluene
DPA – diphenylamine
DTA – differential thermal analysis
EC – ethyl centralite
EDX – energy dispersive x-ray analysis
FA – firearm activity
FBIS – Forensic Ballistics Investigation Section
FCC – fired cartridge case
FDR – firearms discharge residue
FIA – flow injection analysis
FMJ – full metal jacket
FML – Forensic Microanalysis Laboratory
FSG – Forensic Services Group
FSSA – Forensic Science South Australia

FTIR – Fourier transform infrared
FWHM – full width half maximum
GC – gas chromatography
GCMS – gas chromatography mass spectrometry
1,2-GDN – 1,2-glycerol dinitrate
1,3-GDN – 1,3-glycerol dinitrate
GSR – gunshot residue
HEPA – high efficiency particle arrestors
HMF – heavy metal free
HMX – octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC – high performance liquid chromatography
HPLC-MS – high performance liquid chromatography mass spectrometry
ICP-AES – inductively coupled plasma - atomic emission spectrometry
IMS – ion mobility spectrometry
K – potassium
LC – liquid chromatography
LC-MS/MS – liquid chromatography tandem mass spectrometry
LF – lead free
LHS – left hand side
LR – likelihood ratio
MC – methyl centralite
m-cresol – 1-hydroxy-3-methylbenzene
MRM – multiple reaction monitoring
MS – mass spectrometry
MSDS – material safety data sheets
Na – sodium
NA – not applicable
NAA – neutron activation analysis
NATA – National Association of Testing Authorities
NB – nitrobenzene
NC – nitrocellulose
2-NDPA – 2-nitrodiphenylamine
4-NDPA – 4-nitrodiphenylamine
NG – nitroglycerine
NGU – nitroguanidine
NIFS – National Institute of Forensic Sciences
N-NDPA – N-nitrosodiphenylamine
NSW – New South Wales
NSWPF – New South Wales Police Force
NT – nitrotoluene
Pb – lead
PDA – photo diode array
PE – Perkin-Elmer
PETN – pentaerythritol tetranitrate
PMDE – pendant mercury drop electrode
QA – quality assurance
RDX – 1,3,5-trinitro-1,3,5-triazacyclohexane
RHS – right hand side
ROI – region of interest
RWS – Dynamit-Nobel

S – sulphur
Sb – antimony
SE – secondary electron
SEM – scanning electron microscopy
SEM/EDX – scanning electron microscopy/energy dispersive X-ray analysis
Si – silicon
SIM – selected ion monitoring
SMANZFL – Senior Managers of Australian and New Zealand Forensic Laboratories
Sn – tin
SOPs – standard operating procedures
SPC – Sydney Police Centre
SPG – State Protection Group
Sr – strontium
Tetracene – 1-(5-tetrazolyl)-4-guanyltetrazene hydrate
Tetryl – 2,4,6-N-tetranitro-N-methylaniline
Ti – titanium
TIC – total ion chromatogram
TLC – thin layer chromatography
TMJ – total metal jacket
TNB – 1,3,5-trinitrobenzene
TNT – 2,4,6-trinitrotoluene
TOU – Tactical Operations Unit
Triacetin – glyceryl triacetate
UHP – ultra high purity
US – United States
USA – United States of America
UTS – University of Technology, Sydney
VPFSC – Victorian Police Forensic Science Centre
W – tungsten
XRD – X-ray diffraction
XRF – X-ray fluorescence
z – stage height
Z – atomic number
Zn – zinc

**List of Conference
Presentations**

Characteristics of Lead / Heavy Metal –Free Ammunition

*Stephanie Hales, BSc; Claude Roux, PhD; Michael Dawson, PhD;
Chris Lennard, PhD; Eric Davies*

Presented at the 18th International Symposium on the Forensic Sciences,
Fremantle WA, Australia, April 2006 (National ANZFSS Scholarship winner)

A Bayesian Model for GSR Evidence Interpretation

*Stephanie Hales, BSc; Claude Roux, PhD; Simon Walsh, PhD; Chris Lennard,
PhD*

Presented at the 18th International Symposium on the Forensic Sciences,
Fremantle WA, Australia, April 2006 (National ANZFSS Scholarship winner)

**Contamination Prevention Procedures and Their Effect on
Laboratory Background Levels of GSR**

Stephanie Hales, BSc; Chris Lennard, PhD; Claude Roux, PhD

Presented at the 17th International Symposium on the Forensic Sciences,
Wellington, New Zealand, March 2004

**Use of Ion Mobility Spectrometry (IMS) for Detection of GSR in
Shooting Investigations**

*Stephanie Hales, BSc; Elizabeth Chan, BSc; Sonia Casamento, BSc;
Kate McCann, BSc; Joanna Maniago, BSc*

Presented at the 17th International Symposium on the Forensic Sciences,
Wellington, New Zealand, March 2004

**Use of the Environmental Scanning Electron Microscope for the
Analysis of Gunshot Residue**

*Joanna Maniago, BSc; Claude Roux, PhD; Stephanie Hales, BSc;
Matthew Phillips, PhD; Richard Wuhler, PhD*

Presented at the 18th Australian Conference on Microscopy and Microanalysis,
Geelong VIC, Australia, February 2004

Presented at the 17th International Symposium on the Forensic Sciences,
Wellington, New Zealand, March 2004

Presented at the Microscopy and Microanalysis Conference,
Savannah, USA, August 2004

Gunshot Residue (GSR) Evidence Interpretation Issues

*Stephanie Bull, BSc; Sarah Benson, BSc; Claude Roux, PhD; Chris Lennard,
PhD*

Presented at the 16th International Symposium on the Forensic Sciences,
Canberra ACT, Australia, May 2002 (National ANZFSS Scholarship winner)

Propellant & Explosives Analysis by LC/MS/MS

Stephanie Bull, BSc; Claude Roux, PhD; Michael Dawson, PhD; Chris Lennard, PhD

Presented at the 16th International Symposium on the Forensic Sciences, Canberra ACT, Australia, May 2002 (National ANZFSS Scholarship winner)

Presented at the INTERPOL Symposium, Lyon, France, October 2001

Barringer GC-Ionscan: A Field Instrument for Clan Lab Investigations

Karen Scott, BSc; Greg Cook; Stephanie Bull, BSc; Priscilla Barsenbach, BSc

Presented at the 16th International Symposium on the Forensic Sciences, Canberra ACT, Australia, May 2002 (National ANZFSS Scholarship winner)

Presented at Clandestine Laboratory Investigating Chemists 2001

– A Technical Training Seminar, Monterey, California, USA, September 2001

Application of Analytical Chemistry to Forensic Science Problems – an Overview of Method Development and Validation

Claude Roux, PhD; Stephanie Bull, BSc; et al

Presented at Pittcon 2001, New Orleans, LA, USA, March 2001

Investigation Into the Possibility for Secondary Transfer of Gunshot Residue to a Suspect During an Arrest

Stephanie Bull, BSc; Sarah Benson, BSc; Claude Roux, PhD; Chris Lennard, PhD

Presented at the CrimTrac 15th International Symposium on the Forensic Sciences, Gold Coast QLD, Australia, March 2000
(NIFS/SMANZFL Younger Practitioner Award)

Organic Propellant and Explosives Analysis by LC/MS/MS – Preliminary Results

Stephanie Bull, BSc; Claude Roux, PhD; Michael Dawson, PhD; Chris Lennard, PhD

Presented at the CrimTrac 15th International Symposium on the Forensic Sciences, Gold Coast QLD, Australia, March 2000
(NIFS/SMANZFL Younger Practitioner Award)

Presented at the International Association of Forensic Sciences 15th Triennial Meeting, LA, California, USA, August 1999

Abstract

There are two main challenges to gunshot residue (GSR) evidence.

The first concerns analysis. The lack of screening techniques complicates sampling and analysis of large areas or numbers of exhibits. Also, lead or heavy metal free ammunitions present limitations to the technique for confirmatory detection of residues – scanning electron microscopy/energy dispersive X-ray analysis (SEM/EDX).

A screening technique was developed to detect GSR components from all ammunition types. Ion mobility spectrometry (IMS) was proven to allow sensitive and effective screening before proceeding to confirmatory analysis.

Lead and heavy metal free ammunitions were examined and a technique developed for detecting components in the organic portion of the residue. Liquid chromatography tandem mass spectrometry (LC-MS/MS) was extremely effective, detecting twenty seven components. The technique is sensitive (to around 1 ppb), selective, rapid and cost effective. The combination of IMS, SEM/EDX and LC-MS/MS, with visual, physical and microscopic examination, is proposed as a complete protocol for GSR analysis from all ammunition types.

The second challenge involves interpretation. Factors that lead to positive and negative findings must be considered and the weight of evidence assessed. Both background data and application of an interpretive framework have been inadequate.

Background levels of GSR in the NSW general population and NSW Police Force were studied and the chances of random presence on a suspect and of contamination during arrest and sampling process determined.

Nil GSR was detected on hands of the NSW general population or the sample of general duties police officers. A moderate probability was demonstrated for low levels of GSR on hands of crime scene investigators. GSR was detected on hands of all forensic firearms examiners tested, however their role limits access to suspects and items

sampled for GSR, limiting the chance of contamination. Significantly, one high risk area for contamination was identified, the tactical response officers.

Background levels of GSR in the Australian Federal Police laboratories were compared before and after implementing contamination controls. The configuration of the original laboratory along with the lack of controls lead to GSR being detected on almost every sample. The newer laboratory was extremely clean, only one GSR particle being detected, demonstrating the importance of effective contamination controls during sample collection and analysis.

A statistical interpretive framework was developed. The model utilises Bayesian networks to consider existing data relating to transfer and persistence, and new data from this research, providing more objective assessment and allowing broader application of the Bayesian framework.